DEVELOPMENT OF A PERSONALIZED MEAT PRODUCT USING STRUCTURAL-PARAMETRIC MODELING

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Abstract

At present, there is no consistent definition of the term «personalized nutrition». The paper presents existing descriptors in this field of food science: precision nutrition, nutrigenomics, nutrigenetics, individual nutrition and so on. It is noted that cardiovascular diseases occupy the first place among noninfectious diseases associated with malnutrition. Optimal nutrition leads to a reduction in the risk of their occurrence. The methodology of structural-parametric modeling, which allows designing personalized optimal human nutrition based on medical indicators, is presented in terms of minimization of the risk function. The algorithm of a substantiated optimal choice of mass fractions of components (ingredients) of the food recipe composition is given. The main descriptors of a food product with the antisclerotic action for its designing using structural-parametric modeling are shown

Introduction

One of the main prerequisites for maintaining human health is an optimal diet containing necessary macro- and micronutrients.

The results of the studies from 1990 to 2016 (Figure 1) show that the countries of the former USSR occupy 14 of the 20 top places in the rating of deaths from diseases associated with unhealthy diet [1].

According to the research data, cardiovascular diseases are first among noninfectious diseases associated with malnutrition. One of the main prerequisites for maintaining human health is an adequate diet [2]. With the optimal structure of nutrition, high working capacity and primary prophylaxis of many diseases are ensured, immune resistance is increased and protection of the body against exposure to unfavorable environmental factors is enhanced.
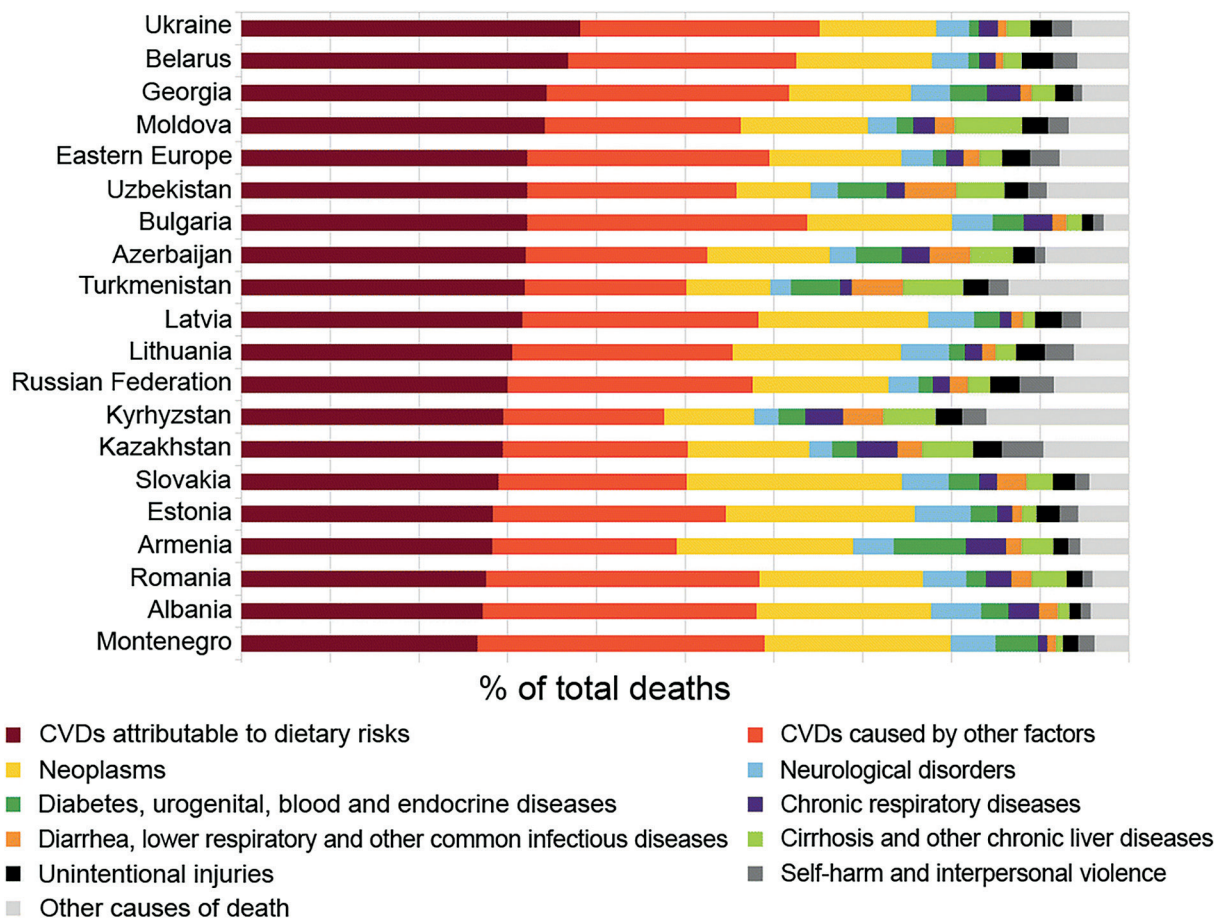

Figure 1. Rating of countries by deaths and their reasons [1]

Production of healthy food was organized for the first time in Japan in 1955. Regulation (EC) No 1924/2006 «On nutrition and health claims made on foods» [3] gives definitions of the terms «nutrition claim», «reduction of disease risk claim», «health claim».

The concept «Society 5.0», which offers the deeper and extended use of digital technologies in all spheres of human life, was presented in Japan in 2016 (Figure 2). According to the strategy «Society 5.0», the advanced technologies entering all life spheres should lead to appearance of new business forms and types and, thereby, to economic rise of the country in general and a growth in life quality of every person individually.

As Figure 2 shows, one of the sustainable development goals of Society 5.0 is creation of «smart» functional foods for personalized human nutrition.

Academician Tutelyan V. A. [5] noted that integration of nutritiology with engineer sciences has been increasing day by day, particularly in the case of food technologies, which creates opportunities for the development of new progressive methods and techniques for designing products with the targeted chemical composition, specialized products as well as diet personalization. The future of integrative nutritiology is creation of digital nutritiology.

The problems of individual (personalized) adequate nutrition of a particular individual with consideration for multiple parameters of the state, alternatives and criteria,

different constraints and conditions can be solved using computer technologies of processing and formalization of knowledge with finding optimal solutions based on models and methods of multi-criteria structural-parametric optimization and objective assessment of adequacy of proposed options.

The paper presents the methodology for the development of structural-parametric models of personalized adequate nutrition, formalization of a knowledge base and creation of an expert system for analysis and correction of a daily diet and nutrition regime for determined human groups with regard for metabolism of nutrients (ethnicity, cultural preferences, health status, lifestyle and clinical factors) from available traditional products in a certain region and modeling an individual (personalized) product by the example of a meat product with antisclerotic action.

Materials and methods

The conceptual approaches of computer design of foods with targeted quality characteristics are based on the principles of structural parametric modeling and optimization of a nutrition system, choice of different types of raw materials and ratios of recipe ingredients, which in combination allow obtaining a composition that corresponds to the fullest extent to the medico-biological requirements and indicators of the nutritional and biological value in terms of the quantitative content and quality composition of nutrients.

Figure 2. Society 5.0 for sustainable development goals [4]

The structural-parametric model [6,7] of a multi-component product reflects functional links between the parameters of the composition and properties of desirable products, as well as many specific factors and ratios that determine the goals, purpose and the use of products under development intended for particular consumer groups.

An advantage of the structural-parametric model of a multi-component product resides in the fact that it permits accounting for the whole variety of factors of nutrient influence on the processes occurring in the human body depending on its metabolism and current physiological state. It provides the means of determining regularities, which knowledge will make it possible to quite confidently talk about possible deviations in a diet and reasons of their appearance, and to find a solution to correct misbalance in the essential elements.

Results and discussion

Personalized nutrition pursues the idea of individualization [8]; recommendations and advice on nutrition should not be built upon average statistical norms for consumption of nutrients applied for age/gender groups of population differentiated by a level of physical activity.

In the personalized nutrition like in other scientific fields, multiple concepts and descriptors are used at the early stage of the development, for example, precision nutrition, stratified nutrition, tailored nutrition.

- Stratified and tailored nutrition are similar. These approaches consist in grouping people with common characteristics and giving recommendations that are suited to each group.
- Personalized nutrition and individually tailored nutrition signify similar concepts and make the following step forward in an attempt to provide nutritional intervention/recommendations that are suitable for a certain person. According to the concept of individually tailored nutrition, many factors are taken into account (such as age, gender, physical activity, anthropometrics, ethnicity, cultural preferences, health status, lifestyle and clinical factors) when developing a diet/food product; however, the parameter of epigenetics is not considered.
- Precision nutrition is the most «ambitious» of the descriptors. It suggests that it is possible to have sufficient quantitative understanding of the complex relations between a phenotype of a person (including health) and his/her food consumption. Based on these relations,

recommendations on an individual diet are built. For precision nutrition, a lot of knowledge and regularities with a high degree of scientific confidence are required.

With transition from stratified to personalized and precision nutrition, it becomes necessary to use more and more parameters or characteristics for achieving the targeted goal. For example, stratification can be accomplished using one or several parameters, such as age, gender or health status. In personalized nutrition, it is necessary to account for the complexity of relationships between an individual diet and phenotype; to achieve the goal of precision nutrition, it would be necessary to use a wide range of parameters, possibly, including «big data» approaches.

At this stage of the research, the authors adhere to the concept of designing diets/products of «individually tailored nutrition».

It is necessary to pay attention to two aspects:
1) physiological reactions on products/nutrients;
2) individual behavior models, including preferences, barriers and motives.

Computer expert systems can take into consideration many personal data, such as eating habits (including personal preferences), health state, physical activity, characteristics of sleep and so on. Data analysis and combination can increase the value of health and well-being management for individuals.

Table 1 lists a range of constant to changeable factors influencing human health [9].

Some of the factors (such as smoking, diet and physical activity) can be changed throughout the life, while age or heredity is unchangeable.

Factors influencing health can increase (for example, a high calorie diet combined with low physical activity or its complete absence) or reduce (for example, eating food rich in fibers) a risk level for an individual.

Clinical trials of these factors (biomarkers, such as serum glucose level, blood pressure and so on) show an effect of a diet/food product on health.

When developing an optimal individual food product, the authors propose a dialog algorithm (Figure 3) [10] for determination of the component composition (raw materials of animal and plant origin), their quantity and ratio by specified criteria and constraints. The first stage begins with entering information about an existing daily diet of patients with consideration for their taste characteristics, ethnic traditions, region of living and so on.

Table 1. Factors influencing health

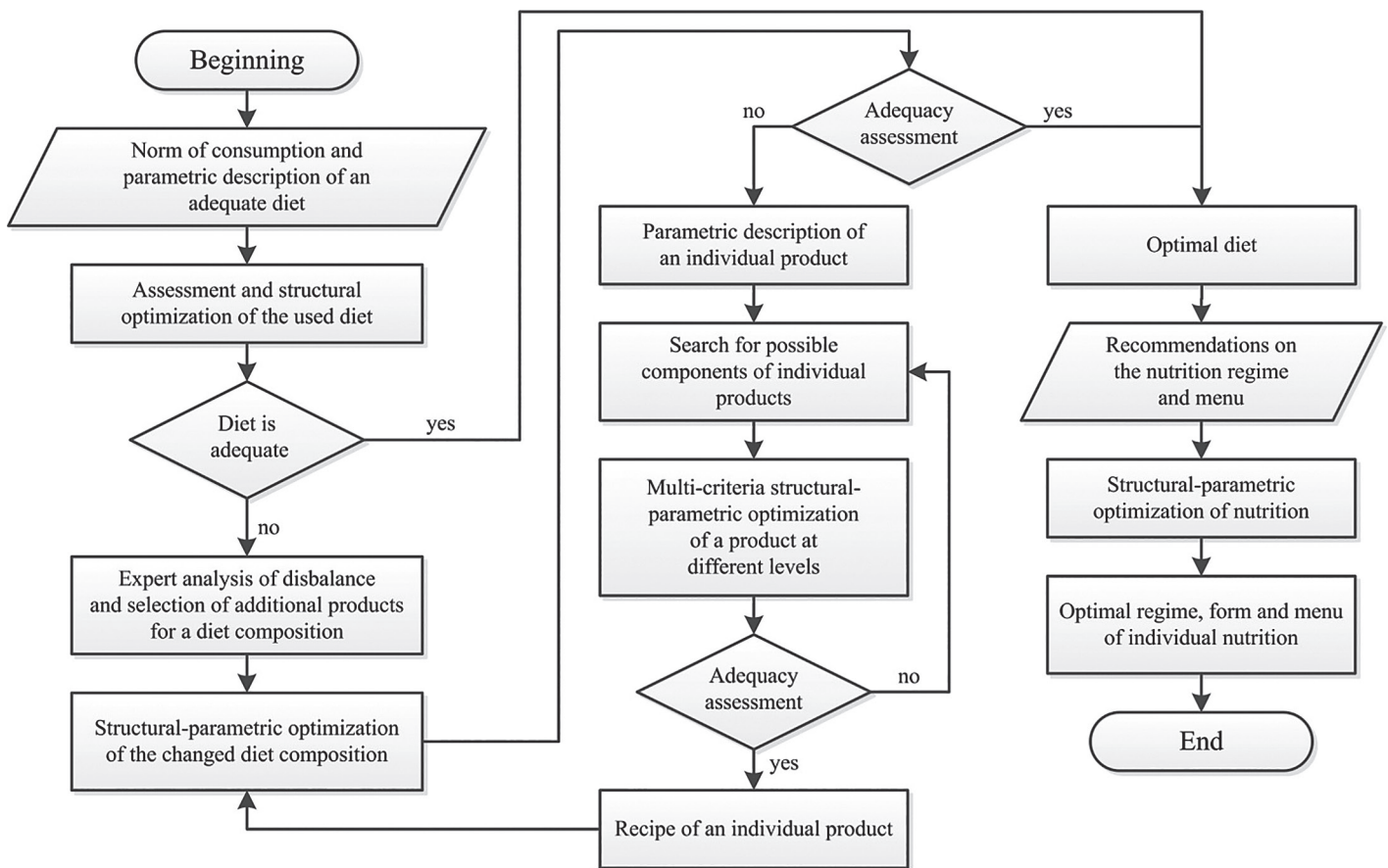| Unchangeable			Easily changeable
• Age	• Medical services	• Education	• Diet/ eating habits
• Gender	• Social structure	• Time for preparation	• Physical activity
• Ethnicity	• Political conditions	• Culinary skills	• Sleep
• Genetics	• Environmental pollution		• Stress
• Family history	• Values		• Hygiene
• Culture	• Purchasing power		• Pharmaceutical drugs (narcotics)

Figure 3. Dialog algorithm of the structural-parametric optimization of the adequate nutrition [10]

Using the described medico-biological status of a person, a parametric model of his/her adequate nutrition is formed in the expert system in terms of specific parameters, norms and ratios of the nutrients and components that are required daily. On this basis, assessment of an existing daily diet is carried out with the normative parametric structure of the indicators of adequate nutrition.

The hierarchy of the quadratic criteria [11] of the minimal deviation from the reference structure of the set of indicators for nutritional, biological and/or energy values, as well as the criteria of protein digestibility, adequacy of protein intake, deficiency of albumin, transferrin, lymphocytes and others are used as a targeted function.

Minimization of the possible noncoincidence between parameters of the «standard» and proposed diets is linked with multi-criteria optimization and formation of the Pareto-optimal set of solutions by formalized criteria.

Upon insufficient compensation of deviations by selection of desired products and dishes that are constituents of a diet, an individual combined functional or specialized product that minimizes established deviations is modeled.

The main task of the development of the individual functional or specialized food product is replenishment of deficient substances in a diet bringing their content to the norms that correspond to the metabolism of nutrients in the human body.

By the example of designing a recipe and product technology for gerodietetic nutrition, let us examine the methodology of structural-parametric modeling of a specialized, functional product.

To this end, the parametric description of scientifically substantiated principles of «diet therapy» for the elderly is downloaded from the Information bank that contains information and knowledge about nutrition of determined groups of people with different noninfectious diseases.

The main input parameters, as was noticed above, are *age* (in our case more *than 60 years*), gender (males), weight (excessive body weight, body mass index more than 30 (BMI ≥ 30), arterial pressure (elevated blood pressure); as an additional factor, an atherogenicity index (an elevated atherogenicity index) is taken into consideration.

When designing nutrition for the elderly, it is necessary to take into consideration the following:
— energy balance of nutrition with regard to actual energy expenditure of the body;
— prophylactic orientation of nutrition and not only regarding *atherosclerosis,* but also other common pathologies of the old age (obesity, diabetes mellitus, hypertonic disease, oncological diseases, osteoporosis and so on);
— correspondence of the food chemical composition to the age-related changes in metabolism and functions;
— balance of diets by all essential factors of nutrition;
— alkaline orientation of nutrition to correct acidotic characteristics of homeostasis (acidification of the body internal environment) that develop in the old age;
— enrichment of diets with products and dishes that normalize intestinal microflora of the ageing body;

— enrichment of food with substances having geroprotective properties;

— the use of foods and dishes that are quite easily subjected to the action of digestive enzymes and assimilation processes;

— the amino acid composition of foods should correspond to the ideal protein FAO/WHO;

— the mass faction of amino acid tryptophan should be not less than 1 g in 100 g of protein;

— the mass fraction of lysine relative to the mass fraction of methionine + cystine should tend to one;

— the ratio of mass fractions of saturated, monounsaturated and polyunsaturated fatty acids should correspond to the ratio of 3:6:1; with that, the set of polyunsaturated fatty acids should include the acids belonging to the ω-3 group (linoleic, linolenic, arachidonic acids), which are crucial components in treatment and prophylaxis of cardiovascular diseases, as they can prevent the formation of cholesterol and triglycerides in blood, increase resistance of the body to infectious diseases in combination with such amino acids as arginine and glutamine, improve renal function, alleviate inflammation processes in the intestine and joints;

— the ratio of the protein mass fraction to the lipid mass fraction should be 1:0.8;

— the energy value of 100 g of a finished product or dish should be in a range of 600–650 kJ;

— products, dishes in a diet should contain vitamins E, C, PP and B group, which presence in a product facilitate retardation of the ageing process; minerals — potassium, calcium, magnesium, phosphorus, iron, selenium, zinc, as well as components that inhibit processes of lipid membrane oxidation, stimulate peristalsis and facilitate regulation of cholesterol metabolism.

A special role in developing a diet for the elderly is assigned to the selection of products and dishes. All of them should be finely dispersed, their consistency should be tender. It is associated with the difficult process of digestion and assimilation in the gastrointestinal tract of the elderly.

In this connection, a choice of a product type from an assortment line of meat products is extremely important when developing meat gerodietetic products. On this basis, paste is most suitable among all types of meat products.

After choosing a product type it is necessary to determine its purpose: in our specific case it is a product intended for dietetic nutrition aimed at reducing risks of development and prophylaxis of hyperlipidemia and atherosclerosis.

When solving the set task, it is necessary to choose correctly raw material sources. Having the above mentioned data and based on the database of raw material composition, it is possible to formalize the requirements to the product composition.

The restricting parameters for *meat raw material* were the protein content not less than 18% and fat content not higher than 15%; the presence of tissue specific peptides with the molecular weights of 809.4 ± 1.0; 776.5 ± 1.0; 765.6 ± 1.0; 739.2 ± 1.0; 710.8 ± 1.0; 229.2 ± 1.0; 162.1 ± 1.0; 156.0 ± 1.0; 148.1 ± 1.0; 140.2 ± 1.0 and 133.1 ± 1.0 Da; the presence of Ano 1 (takes part in formation of high-density lipoproteins), which can be confirmed by the presence on an electrophoregram of the stained spot with characteristics of 25.0/4.95 Mm (kDa)/pl (or calculated value of 30.3/5.38 Mm (kDa)/pl) or the presence of pre- Ano A-1 (takes part in inhibition of oxidative stress) confirmed by the presence on an electrophoregram of the stained spot with characteristics of 25.0/5.0 Mm (kDa)/pl (or calculated value of 30.0/5.47 Mm (kDa)/pl); for *plant raw material* — the protein content not less than 7% and fat content not more than 6%.

As a result of the work with the database for a product under design, the *porcine aorta*, which contains 22 tissue-specific peptides with the molecular weight of up to 2000 Da including biomarkers apolipoprotein A1 and peroxiredoxin, was chosen as a main raw material.

Then, it is necessary to select the mass fractions of chosen recipe components (porcine aorta, porcine heart, potato starch) in such a way that the finished product corresponds to the requirements for gerodietetic products.

In the process of modeling, a range of variation of the mass fraction of each recipe ingredient is determined so that the obtained product levels the pathological processes and reduces a risk of the development of hyperlipidemia and atherosclerosis and also could not negatively affect the organoleptic properties of the finished product (at this stage, the targeted function is also determined).

As paste was chosen from the available range of meat products, the traditional specific functional and organoleptic characteristics (tender, pasty-like consistency), as well as an effect of the technological process stage in its preparation on changes in the composition and properties of raw materials (the structure, structural-mechanical characteristics, ratio of moisture, protein and fat) should be taken into consideration in calculation of the recipe composition.

The task of structural-parametric optimization of a multi-component product in different settings and combinations of linear and non-linear criteria and constraints is solved by simulation modeling using all possible combinations of the initial recipe components with the following verification of constraints and calculation of criteria by the algorithm presented in Figure 4.

A search for an optimal composition of an individual functional or specialized food product from *m*-components begins from selecting the mass fraction of the first component X1 and specifying the initial values nj=n0 of the Kj ratio factors (j=2, m-1), that determine the proportion of the jth component in the total mass fraction of the components j, j+1, …, m. The zero value Kj=0 means an absence of the jth component in the remaining mixture, and Kj=1, respectively, means an absence of all other components except the jth.

Beginning

$m, n_0, h, \min_j, \max_j, j = \overline{1, m}$

$X_1 = \min_1, \max_1(h)$

End

$n_j = n_0; j = \overline{2, m-1}$

$K_1 = X_1; j = 2$

1

$K_i = n_i; 0.9(h)$

$X_j = \dfrac{(1 - K_{j-1})}{K_{j-1}} \cdot X_{j-1} \cdot K_j$

$X_j < \min_j$ — yes / no

2

$X_i > \max_i$ — no / yes

$n_j = K_j$

$n_j = n_0$

$j = j + 1$

$j = j - 1$

$j \leq m + 1$ — yes / no

$j = 1$ — yes / no

$X_m = \dfrac{1 - K_{m-1}}{K_{m-1}} \cdot X_{m-1}$

$n_j = n_j + h$

1

$x_m > \max_m$ — yes / no

$n_j = n_0$

$x_m < \min_m$ — yes / no

? AAS — yes / no

$j = j - 1$

$n_j = n_j - h$

Calculation, minimization and printing of the adequacy criteria
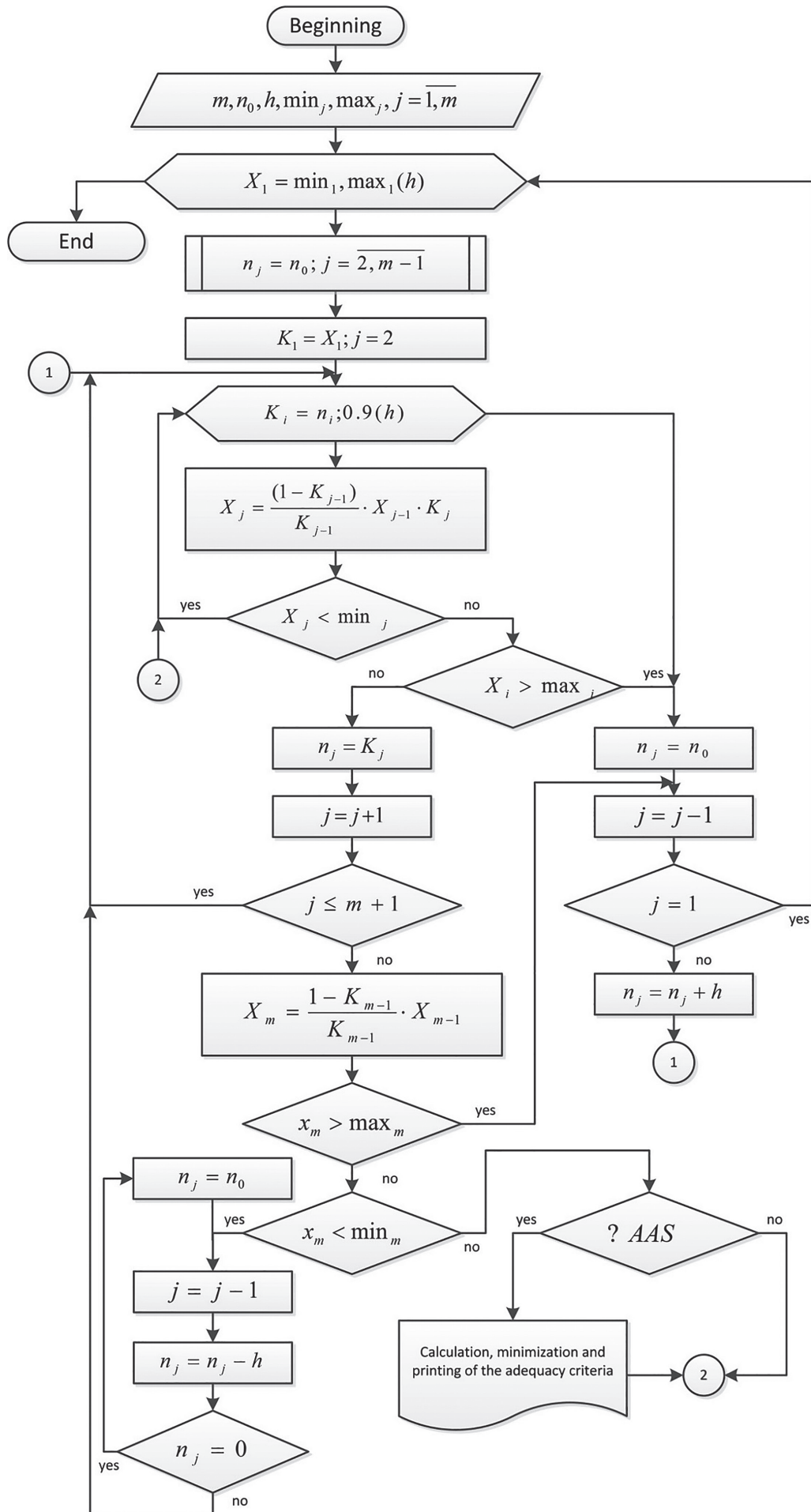
2

$n_j = 0$ — yes / no

Figure 4. Algorithm of structural-parametric optimization of m-component foods by the method of simulation modeling

Therefore, when presetting a cycle of the trial of the Kj ratio factors (j=2, m-1) from some initial value nj=n0 to the final 0.9 in increments of h, all combination variants of a recipe of the mth component product are simulated with determination of the mass fraction of the jth component Xj by the recursive equation

$$x_j = \frac{\left(1 - K_{j-1}\right)}{K_{j-1}} \cdot X_{j-1} \cdot K_j, \quad j = \overline{2, m-1} \qquad 1$$

Then, if Xj satisfies boundary conditions, the memorization of the next ratio nj=Kj and transfer to the cycle of the next Kj ratio for the j=j+1th component is followed. When Xj<minj (does not enter the established range of variations), the coefficient of its share participation with the following components is increased by a value of the increment h, and in the case of Xj>maxj (exits beyond the established range), there is a return to the initial jth ratio nj=n0 and continuation of the previous cycle by Kj for the j=j-1th component with the start value nj=nj+h. Similarly, the constraints for the last component at j=m and Km=1 are checked.

After ratios for all recipe components are identified and the mass fractions in total are 1 (one), the parametric and balance constraints with detection of one of the allowable variants of the area of allowable solutions are verified.

As a result of calculations by the method of simulation modeling with consideration for the above mentioned, the distribution of the mass fractions of recipe ingredients with corresponding assessment of the nutritional and biological value of product forcemeat as well as assessment of geroprotective properties are obtained.

Therefore, computer modeling of a diet and food product allows:

1. Assessing actual nutrition (revealing risks of diabetes, excessive weight, cardiovascular diseases and so on);
2. Detecting controlled indicators, which is necessary to carefully monitor (diabetes — the level of glucose, excessive weight — body mass, body mass index, cardiovascular diseases — atherogenicity index, blood pressure and so on);
3. Establishing an individual norm of nutrient consumption based on recording information about physiological parameters, physical and psychological burden, risk or presence of chronic diseases, ecological conditions, habits and lifestyle (parametric description of an individual);
4. Modeling (designing) optimal curative, heath improving, prophylactic and geroprotective diets and food products, corresponding to an individual norm;
5. fulfilling prescriptions: monitoring of controlled parameters, as well as orders regarding a diet, physical activity, physiological status and so on;
6. giving recommendations on a weight change, using BAAs and other means for correction of diet deficiencies [10].

Conclusion

The studies show that spread of diseases, which risks are directly linked with malnutrition (excessive body weight and obesity, disorders of reproductive health as well as cardiovascular diseases, diabetes mellitus, osteoporosis, several malignant neoplasms and others) require a lot of attention to the problem of adequate nutrition. Cardiovascular diseases occupy a special place among these diseases. Prophylaxis is associated with the development of the individual functional foods. There is no question that modern technologies allow accounting for a large number of input parameters with consideration for metabolism of nutrients when modeling products.

This work presents the methodology of structural-parametric modeling, which allows designing personified optimal nutrition for individuals based on their medical indicators in terms of minimization of the risk function.

The choice and substantiation of the recipe composition is shown by the example of a meat gerodietetic product and is based on the principles of structural-parametric modeling.

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REFERENCES

1. Meier, T., Gräfe, K., Senn, F., Sur, P., Stangl, G.I., Dawczynski, C., März, W., Kleber, M.E., Lorkowski, S. (2019). Cardiovascular mortality attributable to dietary risk factors in 51 countries in the WHO European Region from 1990 to 2016: a systematic analysis of the Global Burden of Disease Study. *European Journal of Epidemiology*, 34(1), 37–55. DOI: 10.1007/s10654–018–0473-x.
2. Titov, E.I., Mitaseva, L.F., Glazkova, I.V., Nikitina, M.A. (2007). Analytical researches of structure of students nutrition. *Food Industry*, 1, 30–31. (In Russian)
3. Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. *Official Journal of the European Union*, L, 404, 9.
4. Society 5.0 — a Japanese approach to digitalization of the economic growth. [Electronic resource: https://www.mitsubishielectric.ru/society/profile/files/Digitalization_Japanese%20appproach%20_rus.pdf. Access date 14.08.2019].
5. Tutelyan, V.A. (2018). Evolution and revolution on the way to formation of modern nutritiology. Integrative and digital nutritiology as the nearest future. *Voprosy Pitaniia*, 87(S5), 21–22. (In Russian)
6. Ivashkin, Yu. A. (2000). Structural-parametric modeling of conflict situations in large systems. *Proceedings of the conference «Mathematical modeling of information and technological systems»*, 4, 261–267. (In Russian)
7. Ivashkin, Yu. A., Nikitina, M.A. (2016). A structural-parametric model of adequate nutrition. *Mathematical Methods in Technique and Technologies — MMTT*, 9(91), 151–154. (In Russian)
8. Ordovas, J.M., Ferguson, L.R., Tai, E.S., Mathers, J.C. (2018). Personalised nutrition and health. *BMJ*, June, 361. DOI: 10.1136/bmj.k2173
9. Boyd, A. (2010). Better health for individuals. Level, Vol. 2, McGraw-Hill Australia Pty Ltd, Waterloo Road, North Ryde NSW 2113, 82

10. Nikitina, M.A., Chernukha, I.M., Nurmukhanbetova, D.E. (2019). Principal approaches to design and optimization of a diet for targeted consumer groups. *News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences*, 1(433), 231–241. DOI: 10.32014/2019.2518–170X.28.

11. Ivashkin, Yu. A. (2008). Multi-agent simulation modeling of large systems. Moscow: MGUPB. — 250 p. (In Russian)

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